DEVELOPMENT OF A STATISTICALLY BASED ACCEPTANCE PLAN FOR BRIDGE DECK WATERPROOFING MEMBRANE THICKNESS

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ABSTRACT

This report chronicles the history of bridge deck waterproofing in Ontario from the early fifties to the present. Problems with systems, materials and workmanship are presented along with the steps taken to ensure quality workmanship.

The use of a form-in-place membrane of hot poured rubberized asphalt has been the almost exclusive method of waterproofing since 1972. This system is very effective, providing it is constructed to specification. Poor workmanship and inspection resulted in several sub-standard waterproofing projects, with one bridge leaking through deck cracks within a year due to excessively thin membrane.

A formalized acceptance procedure was developed which required the contractor to become responsible for process control, along with formalized acceptance testing of membrane thickness by the Ministry after construction was complete. A signed report with the thickness measurements recorded, formed the basis of a data bank which was used in the development of a statistically based acceptance plan which includes a price reduction for borderline work.
Data analysis and rational are presented.

TABLE OF CONTENTS

page

Background 1

Specified Thickness Requirements 6
1984 Data 7
1985 Data 10

Discussion 12

Development of Statistically Based Acceptance Plan 13
Adjusted Pay Schedule 21

Implementation 26

References 27

Appendix I: Bridge Deck Waterproofing
Standard Drawing OPSD-508-02

Appendix II: Ministry Directive C-141

Appendix III: Bridge Deck Waterproofing Special Provision No.903

LIST OF TABLES

page

Table1: Interim Acceptance/Rejection Criteria 6

Table2: Membrane Thickness Measurements 11

Table3: Payment Criteria 15

Table4: Estimating the Percent
Defective of a Normal Population 18

Table5: Percent Defective 20

Table6: Percent Payment Curves 23

Table7: Number of Lots Receiving Payment 24

Table8: Price Adjustment Factors 25

LIST OF FIGURES

page

Figure1: 1984 Waterproofing Thickness Measurements 7

Figure2: Population Estimate of Waterproofing Thickness
Measurements (mean 4.7 mm) 8

Figure3: Population Estimate of Waterproofing Thickness
Measurements (mean 5.0 mm) 9

Figure4: 1985 Waterproofing Thickness Measurements 11

Figure5: Linear Pay Schedule 21

Figure6: Pay Factors vs. Percent Defective 22

BACKGROUND

Concrete bridge decks constructed in Ontario between 1956 and 1962 were treated with a silicone sealant prior to surfacing with a hot laid asphaltic concrete wearing surface. The use of the silicone was found not to contribute significantly to the prevention of surface scaling of concrete decks as intended. Neither did it preclude water entry into deck cracks. In 1962 it was decided that an impermeable membrane at the asphalt pavement/concrete deck interface was required which would:

1. Eliminate the instrusion of moisture and de-icing salts into the concrete deck
2. Bond well to the concrete deck.
3. Effectively bridge joints and cracks.
4. Remain sufficiently elastic over all ambient temperatures to prevent failure by cracking.
5. Remain sufficiently stable to prevent distortion or shoving.
6. Be simple to design and construct.

Two waterproofing membrane types: mastic, a hot applied form-in-place system, and emulsion fiberglass, a cold applied layer system, were introduced and constructed on 181 bridges between 1962 and 1964.

In 1964 an investigation into the "Effectiveness of Bridge Deck Waterproofing in Ontario" was conducted by J.T.Corkill and Lee (Ref.1) and concluded in part that "...the two methods have indeed failed in many cases" and as such "they were not succesful as waterproof barriers".

The reasons for failure were determined as a general lack of bonding to the existing concrete deck, failure of the emulsion-coated fibreglass or mastic to act as a moisture barrier at curbs, inability of the materials to bridge cracks and joints, and ineffective drainage of the water which penetrated the hot mix pavement.

Most incidences of inadequate waterproofing and subsequent failures occured in areas generally not more than 4 ft. from the edge of curbs. Many bridges also exhibited 'stripping' of the overlying asphalt pavement, while the presence of dirt and laitance on many bridge decks together with extreme variations in the thickness of the mastic indicated a definite need for improved quality control and workmanship.

With the advent of automatic concrete deck finishing machines, claimed to be able to finish a deck true to cross-section and grade and the policy of checking every load of concrete for slump and air content, a decision was made in 1965 to construct exposed concrete deck riding surfaces. Decks constructed previous to 1965 would still be waterproofed.

In a 1970 investigation into the effectiveness of the waterproofing of the 323 bridges waterproofed since 1965, Blum (Ref.2) concluded in part that "none of the 56 bridges selected for investigation were 100% effectively waterproofed". He further reported:
"The reasons for the failures were many and varied, but perhaps the greatest single factor involved was the lack of inspection and quality control exerted by the District forces during the waterproofing

applications. Design changes initiated as a result of the 1964 investigation on the "Effectiveness of Bridge Deck Waterproofing" towards improving the performance, generally were not implemented." Blum also recommended: "The emulsion membrane system as presently employed should be discontinued as a specified type of waterproofing system."

By 1972 much concern prevailed over the durability of the exposed concrete bridge decks constructed since 1965. Extensive corrosion of deck reinforcement, aggravated by insufficient concrete cover was resulting in spalling of the deck surfaces. Salt brine was also leaking through deck cracks allowing access to steel, deep inside the deck. Of particular concern was the potential corrosion of stressing cables in post-tensioned structures.

These concerns resulted in a new policy of waterproofing and paving all new structures. Mastic membrane waterproofing was retained for use on rigid frame structures only, due to its limited ability to maintain integrity over cracks. A new system of hot applied rubberized asphalt (Asphalt Membrane) was approved for use on all structures. The asphalt membrane system consists of a form-in-place membrane, 4-6 mm thick, covered by 3.2 mm thick protection boards and two 40 mm lifts of hot mix pavement (see appendix I).

In order to assure the quality of materials and construction of waterproofing, a specialist was engaged by Head Office to supervise all Ministry waterproofing. The specialist was successful in assuring materials supplied to the works were of specified quality and that workmanship was also of a consistent high quality. Specifications

and standards were revised to reflect "State of the Art Technology" and a "Manual for Bridge Deck Waterproofing" was prepared for the use of field supervision staff.

Annual spring reviews of the undersides of many bridges waterproofed under the supervision of the specialist revealed no leakage in the waterproofed areas, but seepage of water and efflorescence was noted at deck cracks under sidewalks and medians.

In 1978 the Ministry underwent a major re-organization where Head Office became responsible for policy and monitoring, and the five regions were charged with most of the programme delivery functions. The Head Office specialist was phased out over the following year and the regions became fully responsible for inspection of bridge deck waterproofing.

The quality of materials remained consistently within specified requirements due to a formalized programme of sampling and testing, but the quality of workmanship generally deteriorated over the next five years. This was principally the result of contractors skimping on materials due to a very competitive market.

In 1983 it became evident after several substantialy sub-standard waterproofing jobs (excessively thin membrane) that a formalized system of inspection and reporting was required to ensure quality workmanship. The Ministry at that time had already made a commitment to the development and implementation of a statistically based end result acceptance plan for granular, concrete, and hot mix

materials. In keeping with this objective an interim acceptance plan (Appendix II) was devised in 1983. The plan consisted of a formalized system of testing and acceptance, or rejection. Bridge decks would be divided into lots of 600 m^2 or less for acceptance. After the completion of the work in the lot, each lot was divided into 10 equal sublots and the thickness of the membrane was checked and recorded at a randomly selected location in each sublot. The data generated was then used to develop a final acceptance plan including price reduction for borderline work. The 1983 data was not considered valid when it was discovered that inspection staff had been making the measurements as the work progressed (entering into the process control) instead of waiting until the contractor completed the lot. Construction inspection staff were further advised through correspondence and seminars to remove themselves from the process control and only make their measurements after completion of a lot. The 1984 data collected is considered valid.

SPECIFIED THICKNESS REQUIREMENTS

M.T.C. Form/OPSS 914 requires a 4-6 mm membrane thickness of either mastic or asphalt membrane on the bridge deck. The actual target thickness is 5 mm, but a tolerance is required for the work. A "rule of thumb" is that an asphalt membrane is capable of maintaining integrity over an active crack width, equal to the thickness of the membrane. Since most bridge decks develop cracks sometime in their life, it is not desireable to permit a membrane thickness less than 3 mm.

The interim acceptance plan developed in 1983 provided for acceptance/rejection based on the mean of 10 measurements as per Table 1. Notwithstanding the mean value determined, any area found to be less than 3 mm thick was to be considered rejectable and remedial action taken.

TABLE 1

INTERIM ACCEPTANCE/REJECTION CRITERIA

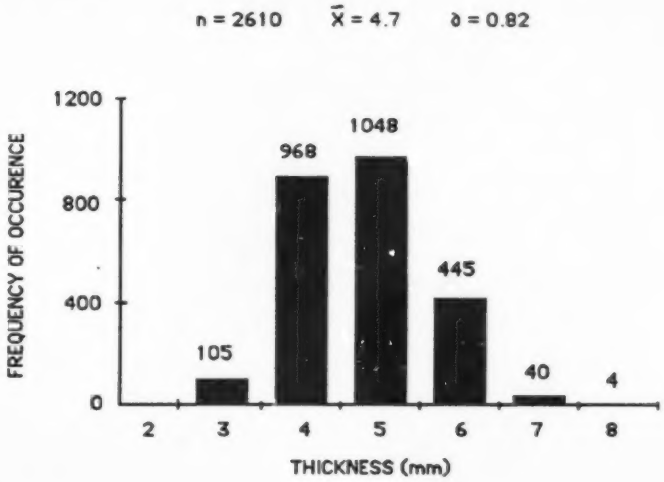
MEAN THICKNESS (mm)				
REJECTABLE	BORDERLINE	ACCEPTABLE	BORDERLINE	REJECTABLE
< 3	$\geq 3 \quad < 4$	$\geq 4 \quad \leq 6$	$> 6 \quad \leq 7$	> 7

1984 DATA

The measurements for 261 lots were received in Head Office and analyzed for mean and standard deviation. Figure1 shows the distribution of thickness measurements in the form of a bar graph.

FIGURE 1

1984 WATERPROOFING THICKNESS MEASUREMENTS



It is interesting to note that out of the total population of 2610 measurements not a single measurement of less than 3 mm was recorded. Subsequent investigation revealed that when thin

membrane measurements were encountered (< 3 mm), the contractor was requested to repair the area and no record was made of the occurence. Although the highest frequency of measurements occurred at the target of 5 mm, there were many more at 4 mm than at 6 mm, which indicates the industry on average is producing a product lower than target. In fact, the mean thickness was computed to be 4.7 mm with a standard deviation of 0.82.

Figure 2 is a representation of a standard distribution curve applied to these values. Figure 3 is the same curve with the mean shifted to the target of 5 mm to determine the effect of improving the process control.

FIGURE 2

POPULATION ESTIMATE OF WATERPROOFING
THICKNESS MEASUREMENTS

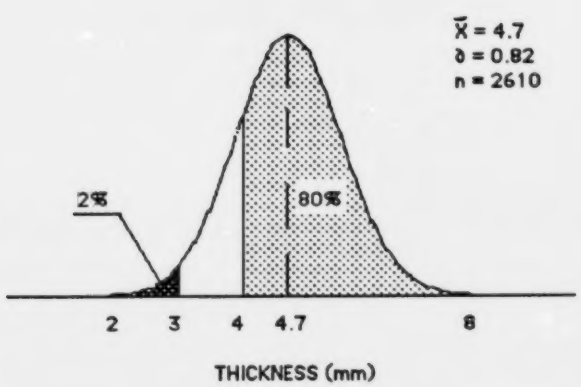
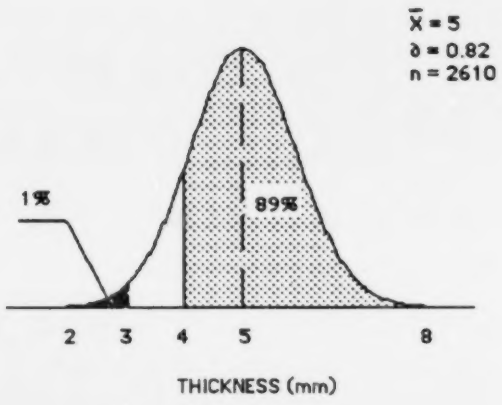


FIGURE 3

POPULATION ESTIMATE OF WATERPROOFING
THICKNESS MEASUREMENTS
(MEAN SHIFTED TO 5.0)



As may be seen in Figure 2, a full 20% of the membrane was less than 4 mm thick, but with the mean shifted to 5 mm with the same standard deviation, only 11% of the material is less than 4 mm. The percent of total population less than 3 mm thick with a mean of 4.7 mm is 2%, and would be further reduced to 1% by shifting the mean to 5 mm.

Comparing lot statistics to the statistics of the total population, the average standard deviation of the 261 lots was found to be 0.75 as opposed to 0.82 for the total population.

1985 DATA

In 1985 there was an increase in the number of lots constructed principally due to the construction of the new Burlington Bay Skyway with a deck area of 44,752 m^2, divided into 75 lots. In total, 306 lots or 3060 measurements were analyzed. The 1985 data corresponded very well with that obtained in 1984 and indicated slightly better results. However, the Burlington Skyway data were found to be complimentary due to excellent process control with an average mean of 5.1 and standard deviation of 0.61 for the 75 lots. With the Skyway data removed from the 1985 analysis the results were the same as in 1984. Figure 4 shows the distribution of results in the form of a bar graph. Table 2 compares the 1984 and 1985 data with the Skyway data included.

FIGURE 4

1985 WATERPROOFING THICKNESS MEASUREMENTS

n = 3060, mean = 4.8, st.dev. = 0.78

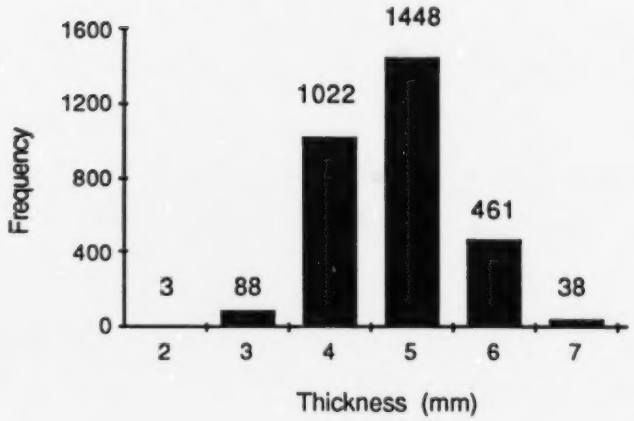


TABLE 2

MEMBRANE THICKNESS MEASUREMENTS

	1984	1985
MEAN	4.7	4.8
ST.DEV.	0.82	0.78
NO. OF SAMPLES	2610	3060

DISCUSSION

Under the interim acceptance procedures, there was no incentive for the contractor to produce a mean membrane thickness greater than 4 mm other than the risk of incurring an occasional thickness of less than 3 mm. On the other hand, there is a financial incentive to produce membrane less than 5 mm thick on average. To demonstrate this financial incentive applying the 1984 provincial mean thickness of 4.7 mm to a lot of 600 m^2, one can estimate the material cost savings for a maximum sized lot.

Thickness less than target: 5.0 - 4.7 = 0.3 mm
% Less than Target: 0.3/5.0*100 = 6%
kg membrane required per m^2 = 6.7
kg membrane required for 600 m^2: 600*6.7 = 4,020
kg material saved by being 0.3 mm thin: 6% of 4,020 = 241
1984 average price/kg (FOB+ Transportation + Tax): $0.80
COST SAVINGS: 241*0.80 = $192.80

This cost savings is roughly equal to the cost of the one union labourer for a day or 25-30% of the labour required to construct the lot.

DEVELOPMENT OF A STATISTICALLY BASED ACCEPTANCE PLAN

The first step in developing the final acceptance plan was to define what was:

1. Required
2. Acceptable
3. Rejectable

1. Required: All membrane on the deck between 5 and 6 mm thick.

This is in agreement with the existing specification.

2. Acceptable: A mean thickness ≥ 4.0 mm with a very small proportion of the material less than 3.0 mm.

Both the 1984 and 1985 data show that this is what the industry is producing.

3. Rejectable: A mean thickness < 4.0 mm thick and/or a substantial amount of material less than 3.0 mm thick.

A mean thickness of less than 4.0 mm would not satisfy the specification and substantial material less than 3.0 mm thick would seriously compromise the integrity of the waterproofing.

This begs the question of how much material less than 3.0 mm can be tolerated? From the 1984 data, it is estimated that 2% of the membrane placed was in this category. Based on technicial judgement, a limit of 5% less than 3.0 mm was set as the point of rejection.

The following philosophy was applied in developing a statistically based acceptance plan:

i/ membrane meeting all requirements to be paid for at full price,
ii/ membrane not meeting all requirements but not rejectable to be paid for at a reduced price,
iii/ rejectable membrane will not be paid for, and the contractor will be required to bring the lot into acceptable limits.

The acceptance plan was then formed using the following criteria:

i/ acceptance based on lots of $\leq 600\ m^2$,
ii/ each lot divided into 10 equal sub-lots,
iii/ one thickness recorded at a random location in each sublot based on the mean of three measurements at each location,
iv/ full payment for material with a mean thickness greater than 4.0 mm and 0.0% defective,*
v/ reduced payment for material with a mean thickness greater than 4.0 mm and 0.1 to 5.0% defective,*
vi/ rejection of material with a mean thickness of less than 4.0 mm,

vii/ rejection of material with greater than 5.0% defective,*

viii/ rejection possible in some situations with a mean thickness in excess of 6.0 mm thick.

* % defective = estimate of % material < 3.0 mm thick based on U.S. Military Standard 414.

The above is summarized in the matrix of Table 3.

TABLE 3

PAYMENT CRITERIA

MEAN THICKNESS \ %DEFECTIVE	0.0	0.1 - 5.0	> 5.0
< 4.0	REJECTABLE	REJECTABLE	REJECTABLE
≥ 4.0 - ≤ 6.0	FULL PAYMENT	PARTIAL PAYMENT	REJECTABLE
< 6.0	* FULL PAYMENT	* PARTIAL PAYMENT	REJECTABLE

* Possible rejection if excessive thickness is considered detrimental

From the above matrix it can be seen that two criteria must be determined in order to see into which category the lot falls:

1. The mean
2. The % defective

The mean is simply an arithmetic average of the 10 test results within the lot as in equation 1:

$$\overline{X} = \Sigma T/n \qquad \text{equation 1}$$

in which:

$\overline{X}$ = mean thickness of the lot

ΣT = sum of the thickness measurements in the lot

n = number of thickness measurements in the lot (10)

To determine the percent defective it is first necessary to determine the standard deviation which is defined as the square root of the sum of the squares of the deviation of each test result from the mean, divided by 1 less than the number of test results, as in equation 2:

$$\partial = \sqrt{\frac{n^*(\Sigma T^2) - (\Sigma T)^2}{n^*(n-1)}} \qquad \text{equation 2}$$

in which

∂ = standard deviation of the lot

n = number of thickness measurements in the lot (10)

(ΣT^2) = sum of the squares of the thickness measurements

$(\Sigma T)^2$ = sum of the thickness measurements squared

The next step is to determine the quality index or Q value as follows in equation 3:

$$Q = (\overline{X} - L)/\partial \qquad \text{equation 3}$$

in which:

Q = quality index

$\overline{X}$ = mean thickness of the lot

L = lower limit below which the % defective is estimated (3mm)

∂ = the lot standard deviation

All that remains is to determine the estimate of percent defective associated with the computed value of Q. This is accomplished by means of Table 4 which is for a sample size of 10. A different table is used for each sample size (Ref.7).

TABLE 4

ESTIMATING THE PERCENT DEFECTIVE OF A NORMAL POPULATION

SAMPLE SIZE = 10

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.5	5.87	5.73	5.59	5.45	5.31	5.18	5.05	4.92	4.79	4.66
1.6	4.54	4.41	4.30	4.18	4.06	3.95	3.84	3.73	3.62	3.52
1.7	3.41	3.31	3.21	3.11	3.02	2.93	2.83	2.74	2.66	2.57
1.8	2.49	2.40	2.32	2.25	2.17	2.09	2.02	1.95	1.88	1.81
1.9	1.75	1.68	1.62	1.56	1.50	1.44	1.38	1.33	1.27	1.22
2.0	1.17	1.12	1.07	1.03	0.98	0.94	0.90	0.86	0.82	0.78
2.1	0.74	0.71	0.67	0.64	0.61	0.58	0.55	0.52	0.49	0.46
2.2	0.44	0.41	0.39	0.37	0.34	0.32	0.30	0.29	0.27	0.25
2.3	0.23	0.22	0.20	0.19	0.18	0.16	0.15	0.14	0.13	0.12
2.4	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.05	0.05
2.5	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01
2.6	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

Q VALUES ARE COMPUTED BY THE STANDARD DEVIATION METHOD. FOR POSITIVE VALUES OF Q, THE PERCENT DEFECTIVE ESTIMATE IS READ DIRECTLY FROM THE TABLE. FOR NEGATIVE Q VALUES, THE TABLE VALUE MUST BE SUBTRACTED FROM 100.00.

Given that greater than 5.0% defective is rejectable and 0.0% defective will receive full payment, from Table 4 we can see that:

a/ the lowest Q value to receive reduced payment would be 1.57, equal to 4.92% defective,

b/ the highest Q value to receive reduced payment would be 2.64, equal to 0.01% defective.

To avoid the need to compute the Q value to determine the percent defective, a table was formulated to yield the percent defective given the mean and standard deviation. Table 5 provides the percent defective (< 3 mm) at the intercept of the mean on the horizontal axis and the standard deviation on the vertical axis. To use the table the mean must be rounded to the nearest 0.1 and the standard deviation to the nearest 0.05. Only half of the full table is presented.

TABLE 5

PERCENT DEFECTIVE (<3 mm)

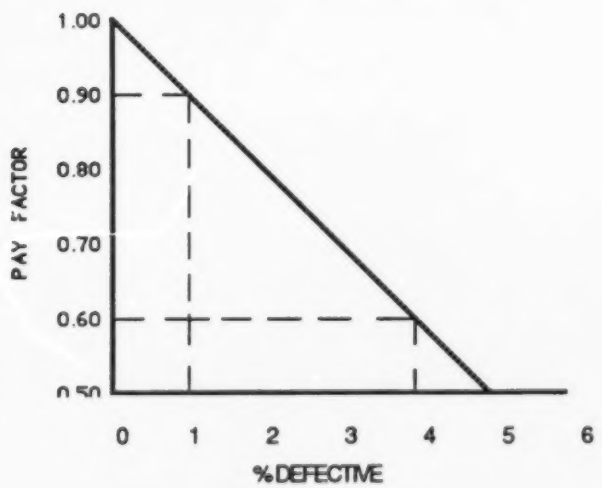
SD/Mean	< 4.0	4.00	4.10	4.20	4.30	4.40	4.50	4.60	4.70	4.80	4.90	5.00
0.30							ACCEPTABLE					
0.35	0.02											
0.40	0.32	0.04										
0.45	1.17	0.39	0.08									
0.50	2.49	1.17	0.44	0.11								
0.55	4.06	2.32	1.17	0.49	0.15	0.02						
0.60	5.87	3.73	2.25	1.17	0.52	0.19	0.04					
0.65		5.31	3.52	2.09	1.17	0.58	0.22	0.06	0.01			
0.70			4.92	3.31	2.02	1.17	0.61	0.25	0.08	0.02		
0.75			6.32	4.54	3.11	1.95	1.17	0.64	0.30	0.11	0.03	
0.80				5.87	4.30	2.93	1.95	1.17	0.67	0.32	0.13	0.04
0.85					5.45	3.95	2.83	1.88	1.17	0.67	0.34	0.16
0.90						5.05	3.73	2.66	1.81	1.17	0.71	0.39
0.95							4.79	3.62	2.57	1.81	1.17	0.71
1.00							5.87	4.54	3.41	2.49	1.75	1.17
1.05								5.59	4.30	3.31	2.40	1.75
1.10									5.18	4.06	3.11	2.32
1.15										4.92	3.95	3.02
1.20				REJECTABLE						5.87	4.79	3.73
1.25											5.59	4.54
1.30												5.31
1.35												
1.40												
1.45												
1.50												
1.55												
1.60												
1.65												
1.70												
1.75												
1.80												
1.85												
1.90												
1.95												
2.00												

ADJUSTED PAY SCHEDULE

The payment adjustment schedule was set at 100% for 0.0% defective down to a minimum of 50% payment at 5.0% defective. Using a linear relationship as shown in Figure 5, a 1.0% change in % defective would result in 10% change in the pay factor. Although this rate of change seems appropriate in the 3-5% defective range, a 10% reduction of pay for only 1.0% defective is considered excessive. A fair adjusted pay schedule is one that is only mildly punitive for work that almost meets specified requirements and becomes increasingly punitive for work further from requirements.

FIGURE 5

LINEAR PAY SCHEDULE



What is required is a payment adjustment schedule that slowly reduces from full payment and increasingly reduces the further the work digresses from target. Both elliptical and parabolic curve pay schedules were considered, as seen in Figure 6.

FIGURE 6

PAY FACTORS VS. PERCENT DEFECTIVE

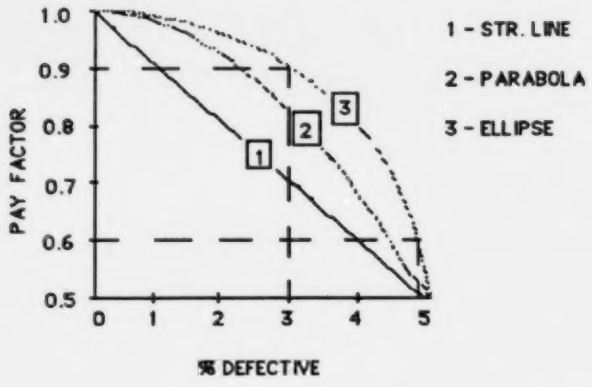


TABLE 6

PERCENT PAYMENT CURVES

% DEFECTIVE	% PAYMENT		
	STR. LINE	PARABOLA	ELLIPSE
0.0	100	100.00	100.00
0.5	95	99.50	99.75
1.0	90	98.00	98.99
1.5	85	95.50	97.70
2.0	80	92.00	95.83
2.5	75	87.50	93.30
3.0	70	82.00	90.00
3.5	65	75.50	85.71
4.0	60	68.00	80.00
4.5	55	59.90	71.79
5.0	50	50.00	50.00

FORMULAS:

STR. LINE: $Y = 100 - 10X$

PARABOLA: $Y = 100 - 2X^2$

ELLIPSE: $Y = \sqrt{(1-X/25)^2 \cdot 2500} + 50$

X = % DEFECTIVE

Y = % PAYMENT

As it may be seen in Figure 6, the elliptical pay factor curve satisfies the above criteria. Before making a final decision on which payment adjustment curve to employ, each of the three was applied to the 261 lots constructed in 1984. Table 7 summarizes the impact of the three curves. As expected, the elliptical curve had the desired impact and was adopted for use.

TABLE 7

NUMBER OF LOTS RECEIVING PAYMENT (1984)

%PAYMENT	STR. LINE	PARABOLA	ELLIPSE
100	98	120	121
100-95	54	71	81
95-90	27	11	14
90-80	20	14	13
80-70	17	8	7
70-60	13	12	3
60-50	11	4	1
REJECT.	21	21	21

For ease of application, the percent defective as illustrated in Table 4, was converted to payment adjustment factors (P.A.F.) using the elliptical formula from Table 6. This permits the direct determination of the payment adjustment factor given the mean and standard deviation of the lot.

The rounding of payment adjustment factors to two places of decimal for incorporation in Table 8 has the effect of permitting full payment (i.e. P.A.F. = 1.00) for up to 0.67% defective. This "gift" could be eliminated by the use of a computer programme implementing several places of decimal to perform the computations. At this point in time, a computer programme is not feasible for field application.

TABLE 8

PRICE ADJUSTMENT FACTORS

(partial table)

STD/MEAN	4.00	4.10	4.20	4.30	4.40	4.50	4.60	4.70	4.80	4.90	5.00
0.40											
0.45	1.00										
0.50	0.99	1.00						ACCEPTABLE			
0.55	0.94	0.99	1.00								
0.60	0.83	0.95	0.99	1.00							
0.65	Rej.	0.86	0.95	0.99	1.00						
0.70		0.59	0.87	0.96	0.99	1.00					
0.75		Rej.	0.71	0.89	0.96	0.99	1.00				
0.80			Rej.	0.76	0.91	0.96	0.99	1.00			
0.85				Rej.	0.81	0.91	0.96	0.99	1.00	1.00	
0.90					Rej.	0.83	0.92	0.97	0.99	0.99	1.00
0.95						0.64	0.84	0.93	0.97	0.99	0.99
1.00						Rej.	0.71	0.87	0.93	0.97	0.99
1.05							Rej.	0.76	0.87	0.94	0.97
1.10								Rej.	0.79	0.89	0.94
1.15									0.59	0.81	0.90
1.20						BORDERLINE			Rej.	0.64	0.83
1.25										Rej.	0.71
1.30											Rej.
1.35											
1.40											
1.45											
1.50											
1.55											
1.60											
1.65											
1.70											
1.75							UNACCEPTABLE				
1.80											
1.85											
1.90											
1.95											
2.00											

BASED ON ELLIPTICAL REDUCTION CURVE
(borderline 0 - 5% below 3 mm)

IMPLEMENTATION

The specialist contractors performing waterproofing for the Ministry were invited to a meeting in December 1985. At this meeting they were briefed on the proposed statistically based acceptance plan and invited to comment on it. Subsequently, a special provision was written incorporating price adjustment factors for borderline work. This special provision was incorporated in all 1986 contracts containing bridge deck waterproofing. Appendix III contains this special provision.

"Guidelines For Field Staff" on the implementation and administration of this new system was published and distributed to the Ministry construction staff.

REFERENCES

MINISTRY PUBLICATIONS

1. Corkill J.T. and Lee G.R. "Effectiveness of Bridge Deck Waterproofing in Ontario", RB:57 (1964).

2. Blum W.E. "Bridge Deck Waterproofing in Ontario", IR:50 (1970).

3. Manning D.G. and Ryell J. "Durable Bridge Decks", RR203 (1976).

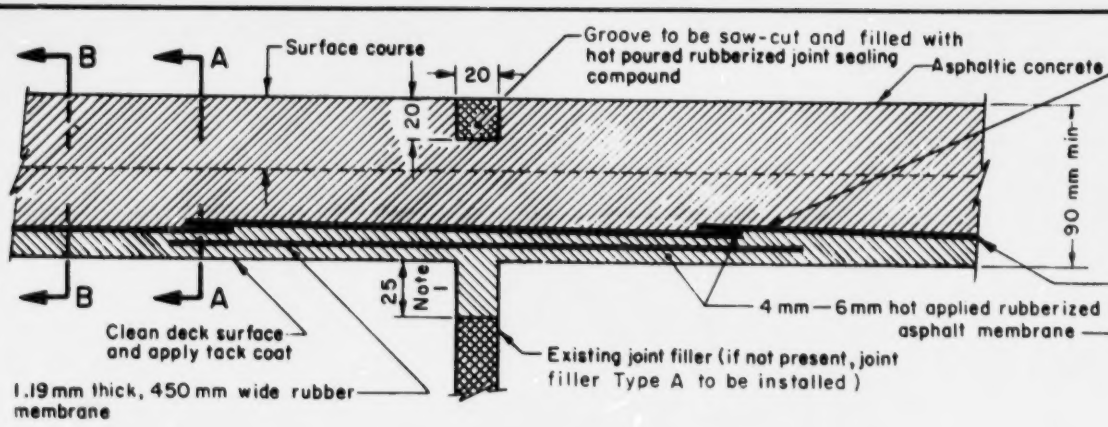
OTHER PUBLICATIONS

4. The Sigma Partnership "Practical Application Of Statistical Quality Control in Highway Construction For Engineers and Technicians", U.S. Department Of Transportation (1979).

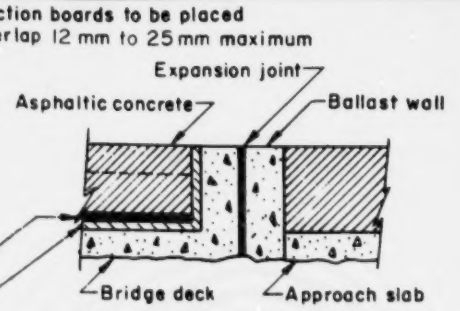
5. Willenbrock J.H. and Kopal P.A. " A Methodology For the Development of Price Adjustment Systems For Statistically Based Restricted Performance Specifications", Pennsylvania Department Of Transportation (1976).

6. Willenbrock J.H. and Kopac P.A. "The Development of Tables For Estimating Percent of Material Within Specification Limits", Pennsylvania Department Of Transportation (1976).

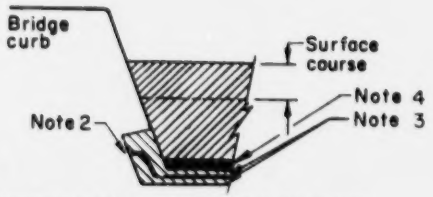
7. Weed R.M. "Statistical Specification Development", New Jersey Department OF Transportation (1982).


B
A
Surface course
20
Groove to be saw-cut and filled with hot poured rubberized joint sealing compound
Asphaltic concrete
Protection boards to be placed to overlap 12 mm to 25 mm maximum
20
90 mm min
25
Note 1
Note 4
4 mm — 6 mm hot applied rubberized asphalt membrane
Clean deck surface and apply tack coat
Existing joint filler (if not present, joint filler Type A to be installed)
1.19 mm thick, 450 mm wide rubber membrane

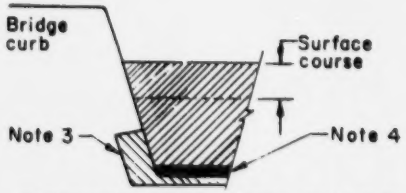
SECTION OVER FIXED JOINTS AND CONSTRUCTION JOINTS



SECTION OF DAM AT EXPANSION JOINT



SECTION A-A WITH CHASE



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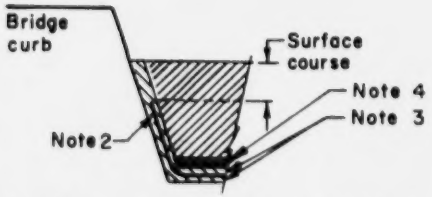
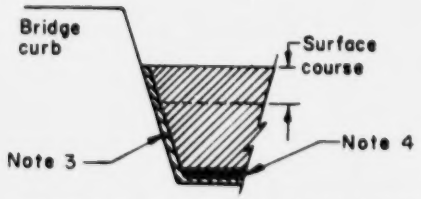
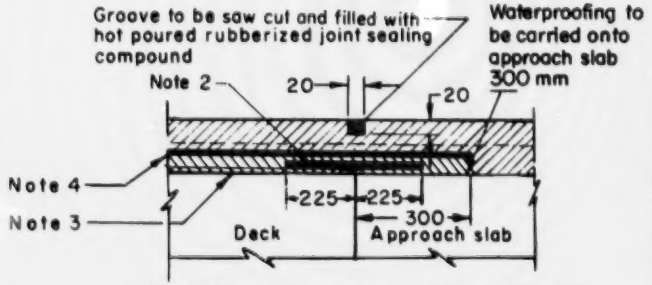


SECTION A-A WITHOUT CHASE



SECTION B-B WITHOUT CHASE



SECTION OF JOINT BETWEEN DECK & APPROACH SLAB

NOTES:

1 Existing joint filler to be removed as shown. Depth may vary when installing a neoprene joint filler at expansion joint.

2 1.19 mm thick x 450 mm wide rubber membrane.

3 4 to 6 mm hot applied asphalt membrane.

4 3.2 mm x 1.0 m x 1.5 m asphalt impregnated waterproofing protection board.

A Protection boards to be cut within 6 mm of curb.

B All dimensions are in millimetres or metres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Date	1984 10 01	Rev	1
BRIDGE DECK **WATERPROOFING** HOT APPLIED ASPHALT MEMBRANE WITH ASPHALT IMPREGNATED PROTECTION BOARD	Date _____			
	OPSD-508.02			

Ministry of Transportation and Communications
Ontario

MINISTRY DIRECTIVE

Program: Provincial Highways

Directive: C-141

Issuing Authority: Executive Director, Highway Engineering Division

Date of Issue: 83 05 09 Effective Date: Immediate

TO: Executive Directors, Regional Directors, Directors, District Engineers, Regional Managers Drivers and Vehicles, Office Managers

SUBJECT: Acceptance/Rejection Guidelines for Bridge Deck Waterproofing Membrane Thickness

ALTERNATIVE INDEX LISTING(S): Bridge Deck Waterproofing, Interim Policy

PURPOSE: To establish an interim policy for the acceptance/rejection of non-conforming work.

REFERENCES:
- MTC Form 914, Construction Specification for Bridge Deck Waterproofing.
- Provincial Roads Directive B-42, Minimum Frequencies of Sampling and Testing for Construction Materials.
- Construction Manual, Part 6.
- Engineering Materials Office, Bituminous Section - Tel. 248-3688.

BACKGROUND: Performance type specifications currently under development will provide formal acceptance/rejection criteria, probably accompanied by some type of contractural incentive such as price adjustment.

In the interim it is necessary to define the Acceptable, Borderline and Rejectable Zones and policies for acceptance and rejection of material within these zones.

POLICY:

1. General

i) Process control is the Contractor's responsibility.

ii) Membrane thickness will be measured for acceptance/rejection after the complete construction of a lot.

iii) Acceptance/rejection of membrane will be based on the mean thickness within a lot.

iv) Membrane less than 3 mm thick will not be accepted regardless of the mean thickness of the lot.

2. Determination of Lots

- Each lot shall contain a maximum 600 m^2.
- Decks of less than 600^2 will be considered a single lot, unless they are split longitudinally for staged construction, in which case each side will constitute a lot.
- Decks larger than 600 m^2 shall be divided into equal lots. Should the deck be split longitudinally for staged construction, each side shall be treated as a separate deck.

3. Testing

Ten random locations within each lot shall be selected for testing as per the detailed instructions attached. The thickness of the membrane shall then be measured at each location. The ten measurements shall be recorded and the mean of the measurements computed on Form PH-CC-129.

4. Acceptance/Rejection Criteria

The values in the following table outline the Acceptable, Borderline and Rejectable Zones for the mean thickness in each lot.

Thickness (mm)				
Rejectable	Borderline	Acceptable	Borderline	Rejectable
< 3	$\geq 3 - < 4$	$\geq 4 - \leq 6$	$> 6 \leq 7$	> 7

(a) Acceptable Membrane

Membrane thickness falling in the Acceptable Zone will be accepted in the work. If any single measurement is less than 3 mm then (d) below will apply.

(b) Borderline Membrane

Membrane of borderline thickness will be accepted in the work. If any single measurement is less than 3 mm then (d) below will apply. Where the mean test results fall outside the Acceptable Zone but in the Borderline Zone, a letter of instruction is to be issued to the Contractor outlining the extent of specification non-compliance. This letter should include a warning that if the quality of work does not return to the Acceptable Zone, an infraction report will be submitted for each recurrence. An infraction report is to be submitted for each subsequent occurrence.

(c) Rejectable Membrane

Membrane falling in the Rejectable Zone will not be accepted in the work. Where the mean test results fall in the Rejectable Zone, a letter of instruction is to be issued to the Contractor requiring him to increase the membrane to specified thickness. With the asphalt membrane system, the complete removal of the protection boards would be required. Reuse of removed protection boards is not to be permitted. An infraction report is to be submitted for each occurrence in the Rejectable Zone.

(d) Measurements Less Than 3 mm

Any membrane found to be less than 3 mm thick is rejectable regardless of the computed mean thickness. If the computed mean falls in the Acceptable or Borderline Zone and any individual measurement is less than 3 mm, the limits of the deficient area must be determined and the membrane thickness increased to specified thickness. A letter of instruction is to be issued as in borderline membrane.

(e) The Project Supervisor should discuss the acceptance procedure to be used with the contractor at a field meeting prior to the start of the waterproofing work.

IMPLEMENTATION: Immediately.

- ooo -

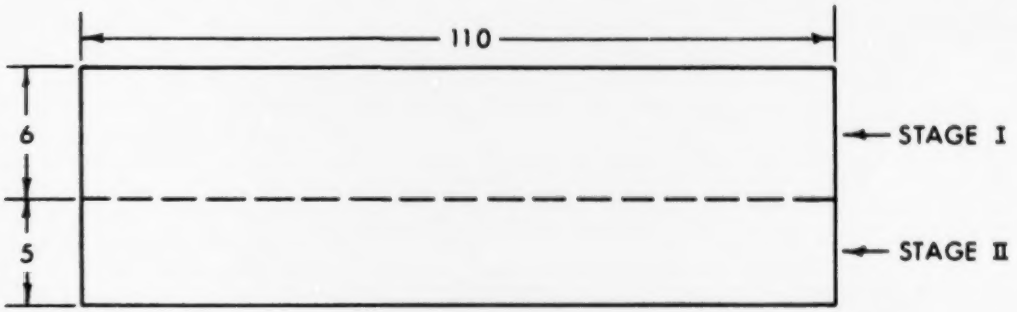
Appendix 1

DETERMINATION OF SAMPLE LOCATIONS FOR BRIDGE DECK WATERPROOFING MEMBRANE

Example

Determination of random sample locations for bridge deck waterproofing membrane thickness.

A bridge deck 110 metres long by 11 metres wide is to be waterproofed in two stages, so as to maintain traffic on one side. The Contractor wishes to waterproof 6 metres wide on the first side.



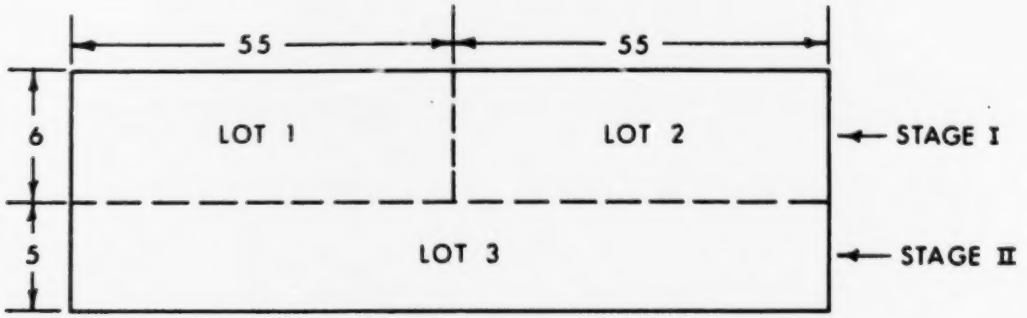
Step 1 Compute the area of each stage.

Stage I $6 \times 110 = 660\ m^2$
Stage II $5 \times 110 = 550\ m^2$

Step 2 Determine lot sizes.

Since the first stage will have in excess of 600 m^2 it must be divided into two equal lots, each 55 metres long.

The second stage has an area under the 600 m^2 criteria and is therefore to be considered a single lot.



Step 3 Enter Random Number Table

After the Contractor has completed waterproofing a lot, the test locations are obtained by using random numbers.

From the Random Number Table select ten random numbers from a vertical or horizontal row.

e.g.

.958	.863	.912	.012	.219	.201	.384	.291	.661	.633
.142	.784	.288	.910	.049	.644	.327	.345	.535	.310
.433	.412	.427	.996	.174	.318	.931	.006	.345	.263
.717	.976	.232	.083	.936	.094	.092	.391	.953	.688
.919	.370	.939	.575	.765	.539	.619	.308	.705	.829
.324	.637	.533	.659	.026	.617	.348	.218	.935	.463
.015	.004	.485	.594	.102	.942	.726	.295	.328	.489
.870	.204	.854	.547	.527	.552	.958	.454	.024	.689
.433	.152	.722	.656	.224	.358	.385	.667	.156	.647
.082	.502	.347	.393	.303	.295	.637	.307	.507	.689
.119	.057	.188	.474	.713	.138	.689	.004	.255	.903
.297	.713	.871	.658	.215	.353	.876	.045	.765	.864

The numbers in the row will be used to determine the offset location from one edge of the lot.

Step 4 Compute test locations to the closest 0.1 m.

To determine the longitudinal distance between sample locations from one end of the lot, divide the length of the lot by eleven.

The offset from one side of the lot is determined by multiplying the random number by the width of the lot.

e.g. Sample Locations for Lot No. 1

$$\frac{55}{11} = 5 \text{ m}$$

Sample No.	Distance (m)	Offset (m)
End of Lot	0	
1	5	6 x .661 = 4.0
2	10	x .535 = 3.2
3	15	x .345 = 2.1
4	20	x .953 = 5.7
5	25	x .705 = 4.2
6	30	x .935 = 5.6
7	35	x .328 = 2.0
8	40	x .024 = 0.1
9	45	x .156 = 0.9
10	50	x .507 = 3.0

Step 5 Measure and record membrane thickness at each test location.

Mark out each computed test location on the deck.

With the asphalt membrane system, employing protection boards, you must select the closest upper corner of a protection board to your sample location. Lift up the corner of the board to expose the membrane and measure the thickness at that point.

With mastic membrane; measure the thickness at the computed distance and offset.

The measurement is made with a thin steel scale such as that supplied with a surveyor's chain for temperature correction or a machinist scale obtainable at most hardware stores. The zero end of the scale is worked back and forth in a sawing action until it is in contact with the concrete deck. The thickness of the membrane may then be read directly off the scale.

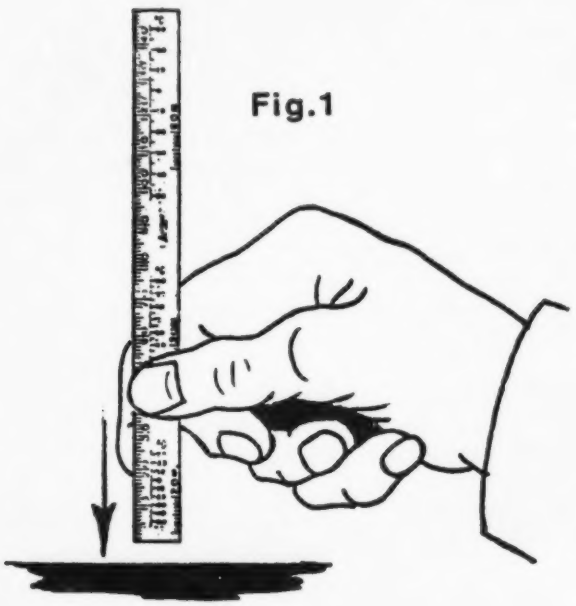


Fig.1

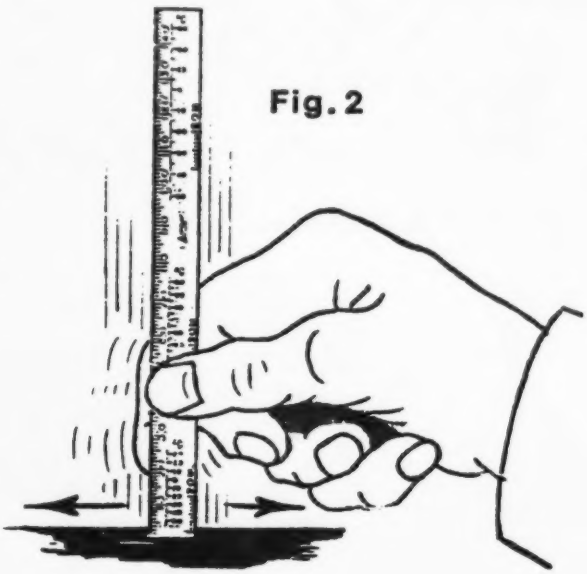


Fig. 2

Step 6 Compute mean thickness

The ten thickness measurements are added and the computed sum divided by 10 to yield the mean thickness. The mean thickness is then compared to the acceptance/rejection criteria and appropriate action taken.

Appendix 1

Ministry of Transportation and Communications

Ontario

_____ OF _____

WATERPROOFING MEMBRANE THICKNESS REPORT

CONT. NO. _____ REGION _____ AREA _____ HWY. _____ SITE NO. _____

AREA OF DECK _____ m^2 NO. OF LOTS _____ MEMBRANE TYPE _____

WATERPROOFING CONTRACTOR _____

LOT NO. _____ DISTANCE BETWEEN SAMPLES = LENGTH OF LOT / 11

SAMPLE NO.	DISTANCE (m)	OFFSET (m)	THICKNESS (mm)
	0	LOT WIDTH x RANDOM NO. = OFFSET	
1		x =	
2		x =	
3		x =	
4		x =	
5		x =	
6		x =	
7		x =	
8		x =	
9		x =	
10		x =	
		SUM ÷ 10	
		= MEAN	

ACCEPTABLE | BORDERLINE | REJECTABLE

CHECK OFF APPROPRIATE BOX

SKETCH DECK INDICATING LOT LOCATIONS	NOTES: (REPORT ACTION TAKEN IF ANY)

_____ Date

_____ Inspector's Signature

DISTRIBUTION: WHITE: Reg. Qual. Assur., YELLOW: Cont'r., PINK: H. O. BIT. Sect., GOLDEN ROD: Field

PH-CC-129 83-05

Appended to PHY Directive C-1

Appendix I

TABLE OF RANDOM NUMBERS - 1

.318	.801	.435	.202	.745	.489	.900	.027	.827	.279
.922	.683	.847	.320	.478	.421	.893	.828	.444	.619
.726	.473	.854	.662	.381	.761	.661	.668	.174	.799
.711	.341	.219	.228	.468	.683	.676	.374	.502	.469
.978	.631	.469	.885	.267	.510	.601	.135	.290	.025
.689	.152	.703	.544	.742	.335	.670	.034	.007	.590
.515	.351	.824	.856	.347	.792	.543	.590	.052	.713
.960	.690	.343	.019	.917	.879	.364	.271	.942	.355
.991	.520	.165	.043	.448	.626	.526	.926	.607	.827
.713	.766	.812	.496	.626	.770	.332	.770	.663	.200
.131	.266	.141	.919	.199	.510	.332	.546	.762	.991
.977	.697	.704	.305	.831	.740	.050	.926	.239	.392
.681	.627	.035	.023	.335	.790	.623	.673	.509	.480
.106	.702	.879	.408	.519	.929	.416	.584	.486	.818
.635	.427	.554	.288	.329	.933	.855	.858	.059	.851
.506	.672	.434	.162	.060	.375	.025	.415	.868	.637
.298	.057	.960	.411	.441	.565	.171	.693	.054	.065
.817	.663	.359	.038	.653	.001	.321	.506	.886	.920
.764	.580	.967	.071	.286	.351	.950	.098	.539	.793
.493	.205	.698	.182	.504	.687	.005	.814	.951	.326
.314	.496	.174	.924	.886	.170	.495	.431	.835	.546
.308	.360	.103	.151	.234	.927	.068	.981	.439	.444
.412	.097	.321	.233	.725	.434	.429	.919	.575	.493
.178	.245	.433	.486	.622	.175	.238	.108	.647	.215
.847	.387	.434	.285	.515	.980	.261	.960	.755	.058
.574	.039	.679	.471	.775	.986	.536	.834	.080	.754
.648	.461	.014	.064	.176	.867	.484	.794	.388	.890
.764	.412	.577	.523	.060	.329	.655	.313	.382	.134
.899	.070	.117	.270	.914	.048	.584	.566	.099	.314
.792	.356	.793	.143	.640	.267	.216	.824	.367	.886
.486	.886	.430	.327	.315	.988	.233	.880	.244	.936
.760	.328	.874	.960	.989	.426	.805	.934	.717	.880
.833	.122	.911	.217	.136	.907	.322	.090	.216	.392
.557	.997	.727	.181	.510	.704	.349	.505	.864	.872
.244	.180	.057	.721	.349	.629	.780	.065	.125	.721
.546	.572	.623	.347	.550	.472	.608	.325	.426	.001
.596	.533	.616	.678	.030	.197	.939	.806	.441	.212
.440	.559	.286	.750	.823	.926	.004	.225	.778	.384
.339	.388	.357	.764	.624	.170	.448	.564	.383	.310
.755	.918	.791	.329	.414	.149	.699	.172	.156	.482

TABLE OF RANDOM NUMBERS - 2

.511	.455	.333	.087	.021	.048	.265	.798	.430	.374
.941	.656	.537	.385	.994	.813	.012	.823	.502	.839
.673	.721	.637	.123	.748	.661	.372	.018	.242	.837
.623	.125	.748	.141	.648	.768	.933	.514	.969	.321
.498	.162	.692	.878	.474	.159	.751	.130	.691	.831
.732	.909	.181	.055	.139	.911	.113	.100	.178	.358
.336	.031	.853	.660	.417	.154	.051	.984	.881	.607
.652	.347	.261	.626	.778	.667	.321	.987	.404	.102
.815	.058	.941	.981	.743	.420	.400	.864	.713	.402
.567	.607	.476	.857	.120	.358	.313	.226	.091	.065
.651	.121	.116	.621	.112	.937	.329	.497	.328	.416
.380	.110	.905	.074	.450	.293	.238	.992	.534	.468
.117	.790	.119	.214	.868	.562	.163	.630	.185	.112
.386	.342	.174	.450	.134	.503	.421	.835	.608	.458
.871	.935	.699	.516	.937	.904	.437	.504	.300	.379
.967	.401	.487	.070	.959	.912	.706	.703	.431	.361
.035	.351	.251	.566	.125	.476	.495	.631	.705	.053
.334	.241	.075	.584	.618	.919	.359	.090	.157	.801
.742	.575	.022	.188	.241	.136	.120	.304	.561	.235
.589	.972	.148	.515	.674	.502	.173	.544	.131	.431
.091	.675	.899	.297	.987	.258	.286	.533	.642	.179
.562	.005	.040	.971	.491	.382	.840	.420	.762	.932
.923	.913	.114	.565	.031	.417	.264	.231	.543	.114
.153	.225	.585	.818	.598	.937	.325	.754	.250	.343
.931	.413	.108	.673	.879	.718	.801	.483	.575	.374
.284	.495	.328	.050	.197	.733	.718	.859	.393	.431
.138	.221	.286	.339	.248	.158	.591	.379	.621	.918
.982	.391	.054	.199	.991	.493	.254	.974	.456	.178
.306	.408	.069	.416	.208	.834	.753	.604	.272	.186
.460	.602	.941	.973	.348	.231	.451	.277	.759	.857
.059	.046	.022	.524	.259	.963	.079	.663	.293	.531
.754	.111	.174	.284	.215	.766	.693	.156	.265	.143
.239	.252	.479	.157	.946	.790	.880	.058	.983	.055
.478	.892	.979	.683	.718	.047	.944	.356	.696	.899
.387	.305	.192	.760	.795	.603	.858	.247	.561	.607
.513	.108	.897	.248	.626	.111	.871	.001	.614	.062
.580	.477	.887	.205	.082	.136	.443	.124	.352	.035
.032	.992	.035	.056	.788	.417	.131	.458	.439	.703
.971	.041	.621	.122	.836	.227	.858	.646	.895	.358
.372	.009	.854	.160	.125	.953	.619	.894	.985	.608

TABLE OF RANDOM NUMBERS - 3

.092	.502	.049	.381	.549	.243	.444	.452	.119	.192
.805	.944	.702	.129	.663	.270	.829	.540	.946	.525
.728	.859	.257	.970	.955	.673	.927	.822	.644	.516
.335	.051	.710	.238	.811	.991	.745	.243	.547	.498
.149	.691	.889	.776	.211	.860	.018	.985	.523	.489
.006	.289	.185	.946	.025	.619	.664	.704	.860	.479
.051	.206	.384	.330	.582	.994	.409	.716	.204	.891
.379	.402	.379	.476	.583	.728	.478	.631	.530	.603
.570	.483	.856	.249	.923	.026	.950	.275	.443	.306
.368	.126	.233	.335	.702	.430	.477	.006	.191	.102
.024	.508	.934	.501	.227	.881	.540	.966	.482	.745
.182	.288	.260	.738	.580	.300	.457	.931	.708	.900
.636	.497	.488	.924	.862	.302	.633	.124	.105	.245
.885	.589	.700	.510	.291	.489	.561	.570	.894	.478
.744	.180	.474	.667	.648	.251	.227	.740	.752	.099
.930	.961	.583	.718	.742	.809	.009	.948	.335	.133
.318	.138	.344	.401	.140	.459	.019	.536	.436	.971
.002	.190	.579	.781	.272	.641	.086	.353	.644	.136
.308	.517	.518	.136	.022	.613	.421	.492	.706	.406
.979	.504	.670	.660	.099	.363	.905	.853	.029	.035
.506	.758	.913	.095	.408	.324	.923	.238	.453	.286
.697	.839	.549	.878	.178	.538	.879	.774	.446	.714
.972	.473	.745	.188	.580	.738	.466	.214	.363	.928
.299	.216	.414	.370	.184	.080	.251	.251	.260	.741
.958	.863	.912	.012	.219	.201	.384	.291	.661	.633
.142	.784	.288	.910	.049	.644	.327	.345	.535	.310
.433	.412	.427	.996	.174	.318	.931	.006	.345	.263
.717	.976	.232	.083	.936	.094	.092	.391	.953	.688
.919	.370	.939	.575	.765	.539	.619	.308	.705	.829
.324	.637	.533	.659	.026	.617	.348	.218	.935	.463
.015	.004	.485	.594	.102	.942	.726	.295	.328	.489
.870	.204	.854	.547	.527	.552	.958	.454	.024	.689
.433	.152	.722	.656	.224	.358	.385	.667	.156	.647
.082	.502	.347	.393	.303	.295	.637	.307	.507	.689
.119	.057	.188	.474	.713	.138	.689	.004	.255	.903
.297	.713	.871	.658	.215	.353	.876	.045	.765	.864
.157	.625	.036	.503	.078	.692	.624	.003	.807	.793
.643	.307	.060	.358	.537	.842	.270	.356	.966	.279
.155	.229	.990	.097	.161	.265	.910	.277	.907	.218
.193	.218	.001	.810	.159	.401	.483	.175	.622	.374

Appendix 1

TABLE OF RANDOM NUMBERS - 4

784	.419	.498	.821	.029	.032	.851	.960	.006	.418
.078	.134	.763	.519	.842	.128	.383	.915	.743	.138
.323	.913	.378	.954	.315	.609	.298	.362	.277	.744
.950	.365	.675	.357	.110	.403	.153	.239	.273	.242
.264	.512	.245	.696	.111	.721	.822	.137	.537	.517
.418	.153	.931	.360	.730	.995	.307	.703	.617	.674
.424	.646	.172	.883	.676	.254	.699	.206	.630	.527
.617	.307	.543	.118	.235	.861	.615	.943	.327	.691
.844	.968	.716	.872	.770	.162	.293	.851	.130	.703
.214	.346	.047	.208	.831	.790	.761	.389	.625	.815
.687	.823	.611	.982	.545	.669	.481	.539	.074	.515
.640	.135	.262	.048	.246	.642	.491	.536	.295	.805
.256	.699	.012	.958	.190	.014	.661	.705	.760	.818
.193	.208	.957	.666	.284	.848	.260	.169	.763	.358
.071	.483	.274	.352	.549	.250	.820	.535	.933	.803
.612	.710	.710	.785	.884	.466	.981	.446	.219	.357
.410	.026	.354	.196	.556	.407	.389	.766	.981	.974
.541	.466	.682	.936	.644	.987	.064	.528	.711	.491
.860	.726	.295	.830	.430	.070	.963	.574	.436	.452
.625	.118	.645	.665	.430	.990	.164	.049	.808	.508
.486	.757	.554	.917	.543	.482	.711	.186	.494	.423
.874	.856	.764	.765	.820	.250	.879	.521	.445	.741
.285	.395	.786	.882	.667	.319	.162	.486	.895	.266
.596	.153	.584	.793	.635	.763	.378	.768	.059	.177
.271	.267	.181	.488	.585	.136	.884	.807	.809	.732
.020	.974	.241	.398	.582	.588	.899	.042	.770	.030
.359	.139	.213	.854	.283	.718	.828	.991	.143	.253
.668	.385	.911	.526	.261	.597	.523	.418	.057	.226
.203	.985	.708	.066	.749	.526	.803	.169	.513	.221
.258	.639	.093	.404	.285	.501	.079	.283	.185	.525
.644	.867	.172	.607	.406	.653	.099	.608	.710	.770
.507	.374	.038	.570	.671	.067	.558	.743	.155	.196
.841	.393	.553	.059	.459	.006	.047	.846	.151	.036
.717	.373	.823	.559	.457	.011	.701	.416	.370	.147
.226	.482	.964	.326	.278	.757	.233	.997	.784	.545
.757	.174	.421	.616	.834	.757	.174	.935	.985	.464
.013	.482	.264	.882	.766	.260	.730	.259	.591	.781
.321	.105	.571	.216	.842	.668	.061	.689	.339	.396
.929	.491	.517	.230	.065	.391	.069	.797	.735	.396
.430	.963	.270	.442	.715	.741	.113	.003	.627	.140

Special Provision No. 903 (OPS) Metric Page 1 of 5 February 1986

BRIDGE DECK WATERPROOFING - Item No.

Scope

This special provision amends the definition, quality assurance and basis of payment requirements of OPSS 914 by the addition of the following:

Definitions

For the purpose of this special provision the following definitions will apply:

Lot: means a single bridge deck, or part of a bridge deck, with a surface of 600 m^2 or less. Decks larger than 600 m^2 shall be divided into the least number of equal sized lots of 600 m^2 or less. Decks split longitudinally for staged construction shall be treated as separate decks. The exact limits of each lot will be determined by the Authority.

Sub-lot: means approximately 1/10th of a lot.

Mean: means the arithmetic average of the test results within the lot.

Standard Deviation: means the square root of the sum of the squares of the deviation of each test result from the mean, divided by 1 less than the number of test results.

Random Location: means a location determined by the Authority based on random numbers, or if protection boards are used, it means the exposed corner of a protection board closest to that location.

Quality Assurance

Acceptance Requirements

The Authority will determine the acceptability of the waterproofing membrane thickness on a lot-by-lot basis.

Testing Frequency

The Authority will obtain a test result from each sub-lot. Each test result will consist of three measurements taken at the corners of an imaginary triangle centered about the random location. The sides of the imaginary triangle shall be approximately 0.1 m. The three measurements will be averaged, rounded to the closest 1 mm and reported as one test result. The measurement will be made according to current Authority procedures and will be made after the Contractor has completed the lot, including the placement of protection board where applicable.

Acceptance Determination

The decision to accept the waterproofing will be based on the mean and standard deviation of the lot as outlined below.

(a) Case 1 - Lot mean is less than 4.0 mm

If the lot mean is less than 4.0 mm the entire lot is unacceptable. In such cases the Contractor shall repair the entire lot as outlined in (d) below.

(b) Case 2 - Lot mean is greater than or equal to 4.0 mm and less than or equal to 6.0 mm

If the lot mean is greater than or equal to 4.0 mm and less than or equal to 6.0 mm, the mean and the standard deviation will be rounded to the closest 0.1 mm and 0.05 mm respectively, and will then be applied to Table 1 to determine if the lot is in the acceptable, borderline or unacceptable range.

If the lot is within the borderline range of Table 1, the contractor may repair the lot as outlined in (d) below, or he may request that the Authority accept the lot as is, with a reduced payment.

If the lot is within the unacceptable range of Table 1, the Contractor shall repair the lot as outlined in (d) below. Once repaired the entire lot will be re-measured and re-evaluated for acceptance as described in this special provision.

(c) Case 3 - Lot mean is greater than 6.0 mm

If the lot mean is greater than 6.0 mm, regardless of the standard deviation, the Authority will review the conditions that the bridge deck will be exposed to and will then designate the deck as acceptable or unacceptable. The reasons for designating the lot as acceptable, or as unacceptable will be discussed with the Contractor; however, the designation of the lot will be made by the Authority. When the lot is designated unacceptable, the Contractor shall repair the lot as outlined in (d) below. Once repaired the entire lot will be remeasured and re-evaluated for acceptance as described in this special provision.

(d) Repair of Work

Whenever the Authority identifies an unacceptable lot, or whenever the Contractor chooses to improve a borderline lot, the Contractor shall make whatever repairs he deems necessary to upgrade the lot. Any protection boards that are removed shall be replaced with new ones. Once repairs have been completed the Contractor shall notify the Authority and the Authority will determine a new set of random locations and will re- measure and re-evaluate the entire lot for acceptance as described in this special provision.

Basis of Payment

(a) Acceptable Lot

If the lot is designated as acceptable the Authority will pay the Contractor the contract price for the lot as bid.

(b) Borderline Lot

If the lot is designated as borderline, the Authority will apply the lot mean and the lot standard deviation to Table 1 and will determine the payment adjustment factor. Such payment adjustment factor will be multiplied by the bid price to determine payment for the lot.

(c) Re-Testing

The Contractor may request re-testing if any or all of the ten sub-lot test values are challenged. If this occurs 10 new thickness measurements are to be taken within the lot by the Authority in the presence of the Contractor. The new test values will then be used to determine acceptance, and the results will be binding on both parties. All of the above shall conform to this special provision.

WARRANT - Always with this Tender Item.

TABLE 1

LOT MEAN

LOT STANDARD DEVIATION

	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	
0.0																						0.0
.05																						.05
.10																						.10
.15																						.15
.20																						.20
.25					ALL SQUARES ABOVE SQUARES CONTAINING PAY FACTORS FORM THE ACCEPTABLE RANGE.																	.25
.30																						.30
.35																						.35
.40																						.40
.45	Acc.																					.45
.50	.99	Acc.											Squares containing Pay Factors form the borderline range									.50
.55	.94	.99	Acc.																			.55
.60	.83	.95	.99	Acc.																		.60
.65	Una.	.86	.95	.99	Acc.																	.65
.70		.59	.87	.96	.99	Acc.																.70
.75		Una.	.71	.89	.96	.99	Acc.															.75
.80			Una.	.76	.91	.96	.99	Acc.														.80
.85				Una.	.81	.91	.96	.99	Acc.	Acc.												.85
.90					Una.	.83	.92	.97	.99	.99	Acc.											.90
.95						.64	.84	.93	.97	.99	.99	Acc.										.95
1.00						Una.	.71	.87	.93	.97	.99	.99	Acc.									1.00

TABLE 1 (Cont'd)

LOT MEAN

LOT STANDARD DEVIATION	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	LOT STANDARD DEVIATION
1.05	Una.	.76	.87	.94	.97	.99	.99	Acc.								1.05
1.10		Una.	.79	.89	.94	.97	.99	.99	Acc.							1.10
1.15			.59	.81	.90	.95	.97	.99	.99	Acc.						1.15
1.20			Una.	.64	.83	.91	.95	.97	.99	.99	Acc.					1.20
1.25				Una.	.71	.84	.91	.95	.97	.99	.99	Acc.				1.25
1.30					Una.	.76	.86	.92	.95	.97	.99	.99	Acc.			1.30
1.35						Una.	.77	.87	.92	.95	.98	.99	.99	Acc.		1.35
1.40							.59	.79	.87	.93	.96	.98	.99	.99	Acc.	1.40
1.45							Una.	.68	.82	.88	.93	.96	.98	.99	.99	1.45
1.50	Una. means unacceptable Range							Una.	.71	.83	.89	.93	.96	.98	.99	1.50
1.55									Una.	.74	.84	.90	.94	.96	.98	1.55
1.60	ALL SQUARES BELOW SQUARES CONTAINING PAY FACTORS FORM THE UNACCEPTABLE RANGE									Una.	.78	.86	.91	.94	.96	1.60
1.65											.64	.79	.87	.91	.94	1.65
1.70											Una.	.88	.81	.87	.91	1.70
1.75												Una.	.71	.82	.87	1.75
1.80													Una.	.74	.83	1.80
1.85														.59	.76	1.85
1.90														Una.	.64	1.90
1.95															Una.	1.95
2.00																2.00